PB88-195177

Impact on Ozone Attainment of CFC (Chlorofluorocarbon) Controls Used to Prevent Future Depletion of Stratospheric Ozone

(U.S.) Environmental Protection Agency
Research Triangle Park, NC

Apr 88

U.S. Department of Commerce
National Technical Information Service
NTIS

PB88-195177

EPA/600/D-88/074
April 1988

IMPACT ON OZONE ATTAINMENT OF CFC CONTROLS USED TO PREVENT FUTURE DEPLETION OF STRATOSPHERIC OZONE

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REPRODUCED BY
U.S. DEPARTMENT OF COMMERCE
National Technical Information Service
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA/600/D-88/074		PB8 8 - 195177 AS

4. TITLE AND SUBTITLE	5. REPORT DATE
Impact on Ozone Attainment of CFC Controls Used To Prevent Future Depletion of Stratospheric Ozone	1988
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
Dale L. Harmon and N. Dean Smith	
9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT NO.
See Block 12	11. CONTRACT/GRANT NO. NA
12. SPONSORING AGENCY NAME AND ADDRESS **EPA, Office of Research and Development** **Air and Energy Engineering Research Laboratory** **Research Triangle Park, NC 27711**	13. TYPE OF REPORT AND PERIOD COVERED Published paper; 4/88 14. SPONSORING AGENCY CODE **EPA/600/13**

15. SUPPLEMENTARY NOTES AEERL project officer is Dale L. Harmon, Mail Drop 62b, 919/541-2429.

16. ABSTRACT The paper discusses the impact on ozone attainment of chlorofluorocarbon (CFC) controls used to prevent future depletion of stratospheric ozone. It has been decided that allocated quotas offer the most attractive approach to limiting the use of CFCs and brominated compounds (halons). This approach should provide for economically efficient reductions. It involves a minimum of administrative costs, is the most easily enforced option, and does not raise any potential legal issues that might result from other options. Control options that might be used by industry to achieve the necessary CFC reductions are evaluated in the Regulatory Impact Analysis (RIA). The most likely long-term control option which may be adopted by most application areas is a chemical substitute. With this option, it may be possible to eliminate 90% or more of the ozone-depleting CFC emissions. A variety of control options hold promise for short-term applicability. Some of the engineering controls may still be applied even after new chemical substitutes (e.g., HFC-134a and HCFC-123) are in use, since the higher cost of these substitutes may justify recovery. EPA is also considering the development of specific regulations limiting CFC and halon use for particular industries to supplement allocated quotas.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution	Pollution Control	13B
Ozone	Stationary Sources	07B
Fluorohydrocarbons	Chlorofluorocarbons	
	Stratospheric Ozone	07C
Stratosphere	Chemical Substitutes	04A
Bromohydrocarbons		

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (This Report)	21. NO. OF PAGES
Release to Public	**Unclassified**	19
	20. SECURITY CLASS (This page) **Unclassified**	22. PRICE A03 12.95

EPA Form 2220-1 (9-73)

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INTRODUCTION

International Protocol

Recognizing the global nature of the stratospheric ozone depletion issue, the United Nations Environment Programme (UNEP) organized negotiations in 1982 aimed at developing an agreement to protect the ozone layer. In 1985, the negotiations resulted in the adoption of the Vienna Convention for the Protection of the Ozone Layer. Following adoption of the Convention there was a break in the negotiations while scientific and economic information was being developed and assessed. Negotiations were resumed in December 1986 and were successfully concluded on September 16, 1987, in Montreal when 24 nations signed a protocol requiring substantial reductions in the most potent ozone-depleting chemicals. Since then over 30 nations have signed. This international agreement represents a concerted effort by the major chlorofluorocarbon (CFC) and brominated compound (halon) producing and consuming nations to respond to the risks from continued reliance on ozone-depleting chemicals.

The Montreal Protocol[1] is a comprehensive agreement for dealing with the threat of stratospheric ozone depletion by anthropogenic chemicals. It has three key components. First, it requires parties to significantly reduce their production and consumption of certain ozone-depleting substances over the next decade. Second, it provides for revision of the requirements based on scheduled, periodic assessments of available scientific, environmental, technical, and economic information. Third, it imposes restrictions on trade in ozone-depleting products with nonparties to minimize the nonparties' potential to deplete stratospheric ozone and to encourage nations to become parties.

The Montreal Protocol will take effect on January 1, 1989, if at least 11 states or regional economic integration organizations representing at least 65% of the 1986 estimated global consumption of the covered substances have ratified the Protocol, and that the Vienna Convention is in force. If these conditions have not been fulfilled by January 1, 1989, the Protocol will enter into force on the 90th day following the date on which the conditions have been fulfilled.

The Protocol identifies two groups of ozone-depleting substances for control. Group I includes CFC-11, -12, -113, -114, and -115. These chemical compounds are fully halogenated and therefore are strong potential ozone-depleters that are either widely used or potential substitutes for those chemicals which are now widely used. Group II includes halon 1211, 1301,

and 2402. Because they contain bromine, these chemicals are even stronger potential ozone-depleters than those in Group I. The Protocol does not place limits on each of the controlled substances. Instead, it places separate limits on the total ozone depletion potential of Group I and Group II controlled substances that a party produces and consumes. A party may produce and consume any mix of the controlled substances within each of the Groups, so long as the total ozone depletion potential of the mix does not exceed the specific limits.

For Group I controlled substances, the Protocol requires each party to reduce in three steps the calculated level of its production and consumption of those substances. For the first step, if the Protocol enters into force on January 1, 1989, each party must limit its calculated levels of consumption and production to 1986 levels in the 12-month period commencing July 1, 1989, and in each 12-month period thereafter. If the Protocol enters into effect on a later date, the reduction to 1986 levels will begin on the first day of the seventh month following the effective date.

For the second step, each party is required to limit the calculated level of its production -- in the period from July 1, 1993, to June 30, 1994, and in each 12-month period thereafter -- to 80 percent of the calculated level of its 1986 production and consumption. For the third step, each party is required to limit the calculated level of its production -- in the period from July 1, 1998, to June 30, 1999, and in each 12-month period thereafter -- to 50 percent of its calculated level of 1986 production and consumption.

For Group II controlled substances, the Protocol requires that each party limit its production and consumption of those substances to the calculated level of its 1986 production and consumption of the same. This limit must be met in the 12-month period commencing on the first day of the 37th month following the date on which the Protocol enters into force (January 1, 1992, if the Protocol enters into force on January 1, 1989), and in each 12-month period thereafter.

Proposed U. S. Regulation

Following the initial concerns raised in 1974 about possible ozone depletion from CFCs, EPA and the Food and Drug Administration acted in 1978 to ban the use of CFCs as aerosol propellants in all but "essential applications." Congress strengthened EPA's regulatory authority in the 1977 amendments to the Clean Air Act. In 1980, EPA issued an Advance Notice of Proposed Rulemaking (ANPR), stating that it was evaluating further restrictions on CFC use. In 1984, the National Resources Defense Council sued EPA, arguing that the ANPR constituted a finding of reasonable threat to the stratosphere, which required EPA to promptly either issue regulations or formally withdraw the ANPR. In 1985, EPA and NRDC were joined by the Alliance for Responsible CFC Policy, Inc. in filing a joint settlement motion calling for a proposed regulatory decision by May 1, 1987, and a final decision by November 1, 1987. In 1986 EPA published its Stratospheric Ozone Protection Plan, which superseded its 1980 ANPR and outlined a program of further research and decision making. The plan called for research and analysis to narrow scien-

tific uncertainties, and proposed that EPA evaluate domestic regulations concurrently with ongoing international efforts to develop a CFC control protocol to protect stratospheric ozone. The consent decree was extended in 1987 with deadlines of December 1, 1987, and August 1, 1988, for proposal and final action, respectively.

On December 1, 1987, as required by the consent decree, new domestic regulations restricting production and consumption of ozone-depleting CFCs were proposed by the EPA Administrator.[2] The proposed rules would fully implement the Montreal Protocol, if it enters into force and the U. S. ratifies it. The Protocol was ratified by the U. S. Senate on March 15, 1988. EPA's assessment of the risks of ozone depletion indicates that the Protocol's control requirements are an appropriate response.

The Protocol leaves it up to each party how to achieve the required reductions in production and consumption. EPA's goal in implementing the Protocol is to provide the market place with flexibility to achieve the required reductions in the most economically efficient manner possible. Two general approaches for achieving the Protocol's required reductions of controlled substances were evaluated. One approach relies on market incentives to achieve low cost reductions in the use of CFCs and halons. Under this approach EPA could either directly restrict the supply of CFCs and halons or assess a regulatory fee on their use. Either would increase the cost of using CFCs which would give those firms with relatively low-cost reduction options an economic incentive to reduce their use of these chemicals. Those firms where no such reduction opportunities exist would continue to use CFCs, although they would have to pay a higher price. Three alternative economic incentive approaches were evaluated: marketable rights based on auctions, marketable rights allocated by quota to past producers and importers, and regulatory fees.

The second general approach is to use the traditional engineering controls and product or chemical bans. It involves EPA's deciding which specific industries or uses of CFCs and halons should be regulated. This approach is the usual way EPA regulates pollution. It was considered alone, and as a supplement to allocated quotas based on the extent to which CFC users may be postponing the adoption of low cost or easy to implement reductions.

EPA evaluated each of these options in light of the following criteria: certainty of achieving the desired environmental goal, economic costs and efficiency in meeting that goal, administrative costs and enforceability, legal certainty, and impacts on small business. EPA decided to implement the Montreal Protocol using a system of allocated quotas. Quotas reflecting the allowable level of production and consumption will be allocated to each of the firms who engaged in these activities in 1986. Trading of allocated quotas will be permitted. Exports and imports of the restricted chemicals will be allowed consistent with restrictions contained in the Montreal Protocol. EPA believes that this approach will provide a low-cost means of achieving its regulatory goal, spur technological innovation, minimize administrative requirements, and facilitate enforcement. EPA is also considering the development of specific regulations limiting CFC and halon use for particular industries to supplement allocated quotas.

A Regulatory Impact Analysis (RIA) to evaluate the costs and benefits of "major rules" is required by Executive Order. The RIA for Protection of Stratospheric Ozone[3] which was completed in December 1987 evaluates various control options for CFCs. The control options evaluated in the RIA were divided into chemical substitutes, product substitutes, and add-on engineering controls/process substitutions. Several factors were considered in assessing the potential emission reduction, capital expenditure, and operating costs for each control. Factors considered with respect to technical feasibility included compatibility with existing equipment, the ability to maintain system efficiency and reliability, and availability of sufficient experience for commercial application. Economic factors of interest included direct capital and operating costs, outlays for system application testing, plant retooling, and secondary costs such as disposal of waste product and increased warranty claims. In addition, social factors such as safety, worker health, and retraining of service personnel were considered although many of these areas are difficult to quantity.

CONTROL OPTIONS

Industry will use a combination of control options in meeting potential CFC regulations. In the RIA, these controls were evaluated and the more favorable options identified.[4] The controls that appear most likely to be adopted by each application area were listed in the RIA and are summarized in Table I. These control options are described briefly in the following sections. The control options evaluated in the RIA but not included in those judged to be most likely to be adopted are listed in Table II. These options were not selected for such reasons as: too costly, inadequate ozone protection potential, low efficiency, too difficult to implement, unproven technology, and poor quality finished product.

Chemical Substitutes

New Chemical Substitutes. HFC-134a appears to be the most promising substitute for CFC-12. Since the physical properties are very similar to CFC-12, a major equipment change for refrigeration and air conditioning applications may not be required. It is close to CFC-12 in operating efficiency. Some drawbacks include a lack of a compatible lubricating oil and higher cost. Toxicity tests to date have shown low toxicity, but final toxicity test results will not be available for about 5 years.

HCFC-123 appears to be the most promising substitute for CFC-11. Limited testing as a blowing agent for rigid polyurethane foam has revealed both positive and negative results. It has performed well in some formulations and has a slow diffusion rate through the polymer material. Drawbacks include slighty higher solvent action, higher thermal conductivity, and higher cost. HCFC-123 is also a potential substitute for CFC-113 in solvent metal and electronic cleaning. HCFC-123 is a very agressive solvent and has a much lower boiling point than CFC-113 which may limit its use. HCFC-123 is also a potential substitute for CFC-11 used as a refrigerant in centrifugal chillers.

HCFC-124 may be a suitable substitute for CFC-12 as a blowing agent in rigid extruded polystyrene foam sheet, extruded low density polyethylene foam, low density polypropylene foam, and polyvinyl chloride foam. Since its diffusivity through the foam is high, there could be problems resulting in collapsed foam.

Currently Available CFCs and CFC Blends. One control option to reduce the use of CFC-11 blowing agent in rigid polyurethane pour-in-place foam is to use more water in the formulation. It may be possible to achieve 100 percent replacement of CFC-11 with water in rigid polyurethane packaging.

HCFC-22 is used as a refrigerant in retail food refrigeration and in commercial air conditioning. It has an ozone depleting factor only 5 percent that of CFC-12. Substitution for CFC-12 will require significant design changes because: it requires a 50 percent higher operating pressure, it has reduced oil solubility which affects compressor lubrication, and it has a high permeation rate through elastomer hoses.

Several blends containing HCFC-22 hold promise for use as substitutes including:

CFC-502 is an azeotropic mixture of 48.8 percent HCFC-22 and 51.2 percent CFC-115. CFC-502 is used in all of the low-temperature and 40 percent of the medium-temperature refrigeration systems in retail food stores. CFC-502 is a potential substitute for CFC-12 systems.

A HCFC-22/HCFC-142b non-azeotropic mixture of 40 percent HCFC-22 and 60 percent HCFC-142b is tailored to have a close match to CFC-12. This mixture has a good potential for use in small hermetically sealed units such as home refrigerators and as an aerosol propellant.

A CFC-11/HCFC-22 mixture can be used in place of CFC-12 in polyurethane poured and sprayed foam. The substitution would result in only a minor reduction in ozone depletion potential. This and other drawbacks will limit the use of this substitute.

A HCFC-22/hydrocarbon mixture has been found to be an acceptable substitute for CFC-12 as a blowing agent for extruded polystyrene sheet.

Dimethyl ether/HCFC-22 mixtures have been used to replace CFC-11 and CFC-12 in some essential aerosol applications.

Solvent Substitutes. A wide variety of organic solvents are used in electronic and metal cleaning. The most commonly used solvents are petroleum solvents, chlorinated hydrocarbons, and CFCs. It is postulated that petroleum solvents or methyl chloroform will be selected where possible as the short term replacement for CFC-113 in solvent cold-cleaning applications. Methyl chloroform and methylene chloride are expected to be the solvent replacements of choice for vapor degreasing. Dry cleaning applications are expected to switch to perchloroethylene or methyl chloroform. A new product which contains a terpene hydrocarbon-based cleaner has recently been announced which can be used to replace CFC-113 for some solvent cleaning and degreasing.

Methylene chloride also competes with CFC-11 as a blowing agent for flexible polyurethane foam. Wider use of methylene chloride is expected for this application. A major barrier to expanded use of methylene chloride is the potential for future regulation regarding in-plant exposure and stack emissions.

Sterilant Substitutes. Control option "10/90 (EO/CO_2)" refers to replacing 12/88 (a 12 percent ethylene oxide (EO) and 88 percent CFC-12 mixture) with a 10 percent ethylene oxide and 90 percent CO_2 mixture. Control option "N_2 purge, then pure EO" refers to a process where the sterilization chamber is purged with nitrogen before sterilizing with pure ethylene oxide. Control option "HFC-134a/EO mixture" refers to the replacement of CFC-12 in the 12/88 mixture with HFC-134a. All three of these options are expected to be used to replace the 12/88 sterilant. The 10/90 (EO/CO_2) has a disadvantage of requiring a much higher operating pressure than 12/88. The N_2 purge, then pure EO option requires the use of pure ethylene oxide which is explosive; therefore, equipment changes are needed to handle the explosive gas. The HFC-134a/EO mixture is still in the development stage and may not be available for 5 to 7 years.

Currently or Previously Used Substitutes. When polystyrene foams were first introduced in the mid-1960s, they were blown almost exclusively with pentane. Industry has shifted away from pentane because of the fire hazards. It is possible to make virtually all thermoformable polystyrene foam sheet using hydrocarbons such as pentane for the blowing agent. Hydrocarbons such as ethylene, ethane, propane, propylene, and methane are used as refrigerants in large industrial refrigeration systems in petrochemical plants. The use of hydrocarbons is restricted by codes and regulations since they are highly flammable. Hydrocarbons are also volatile organic compounds (VOCs) which contribute to ground level ozone formation.

Ammonia is currently used as a refrigerant in most food processing plants, cold storage warehouses, ice houses, skating rinks, and a percentage of the chemical/petrochemical plants. The use of ammonia is restricted since it is both toxic and flammable.

CO_2 has been used as an aerosol propellant but suffers from poor atomization, varying pressure over the life of the can, and occasional inability to expel the entire contents of the can. Some improvements in technology have reduced problems with CO_2, but they have not been completely eliminated.

Product Substitutes

Alternate Insulating Materials. Rigid foam laminated boardstock is used routinely in the construction of a variety of new buildings and as retrofits in existing buildings. The most likely short-term candidate control option for reducing use of CFCs in these applications is to simply use other materials instead of these foam products. The materials most likely to be used are:

Thick Fibrous Glass Batts/Thick Walls/Conventional Stud Spacing
Thick Fibrous Glass Batts/Thick Walls/Wide Stud Spacing

Thick Fibrous Glass Batts/Industrial Insulation Systems
Other Insulation Materials/Conventional Thickness
Other Insulation Materials/Equivalent Insulating Capacity

Substitute Food Containers. Since the 1960s, polystyrene foam products have gradually replaced competing products fabricated from traditional materials. The benefits of polystyrene foams (e.g., light weight, strength, ease of forming, moisture resistance, low cost, and thermal insulation properties) have spurred this growth. With few exceptions, the polystyrene foam serves essentially the same purpose as the material it has replaced. Materials that can be used in place of the CFC blown polystyrene foam sheet for food packaging include hydrocarbon blown polystyrene, solid plastic, plastic film wrap and bags, and paper and foil wraps.

Alternate Packaging Materials. Low density polyethylene and polypropylene are used in a wide variety of applications, from packaging material to athletic equipment. They have unique properties including: cushion effectiveness at a given thickness, unique vibration dampening response, multiple drop protection, strength, creep resistance, minimum package weight and size, low shipping cost, and static discharge protection. Because of these properties, these foams are often used in specially designed package systems such as for a delicate computer product or military weapon. In these applications, replacements may not be readily available. For other applications, alternative products such as expanded polystyrene (EPS) bead, water-blown polyurethane foam, plastic film bubble wrap, and other paper and plastic packaging products can be used.

Alternate Gasket/Flotation Device Materials. Low density polyethylene and polyvinyl chloride foam are used in gasket and sealing materials and in flotation devices. Gaskets can be made from rubber, plastic, or paper products. Flotation devices are still made from air-filled plastic or sealed fabric. EPS bead is also used for flotation.

Alternate Cushioning Materials. Flexible polyurethane foam is the predominant cushioning material, due to its combined advantages of low price, durability, and versatile physical properties. A degree of conversion to technologies that were replaced by flexible polyurethane (e.g., latex foam, built-up cushioning, and natural and synthetic fiberfill) are technically feasible.

Switch to Disposables. To eliminate the need for hospitals to sterilize on site with the sterilant gas mixture 12/88, one control option is to switch to disposables. All items needed for a single surgical procedure would be packaged and sterilized by the manufacturer of the disposable products.

Modified Stirling Cycle. Modified Stirling cycle refrigerators have been used historically for exotic applications such as aerospace and cryogenic cooling. One company is marketing a refrigerated truck trailer using a modified Stirling cycle.

Add-On Engineering Controls/Process Substitution

Recovery/Recycle. The refrigerants from refrigeration and mobile air conditioning equipment can be recovered and recycled at service, rework, and disposal with the use of portable devices which capture the refrigerant from a system rather than vent it to the atmosphere. More seriously contaminated refrigerants can be collected and then cleaned in a central facility, remanufactured, or destroyed. Much of the waste solvent from solvent cleaning operations can be reclaimed by the use of on- or off-site distillation.

Alternate Leak Test Gas. Mobile air conditioning and refrigeration equipment must be leak tested at manufacture, installation, and service. The high ozone depleting CFC-11 and -12 refrigerants which are used to charge the systems are usually selected for leak testing to reduce chances of the refrigerants' being mixed. CFC emissions can be reduced by switching to a less ozone depleting CFC such as HCFC-22 or to a different gas such as helium.

Market Mix. This concept addresses demand for new centrifugal chillers. It is suspected that a portion of future demand for chillers which use high ozone depletion refrigerants can be shifted to units using a lower ozone depleting refrigerant such as HCFC-22. For example, CFC-11 centrifugal chillers are known to be widely used in the range of 300 to 1000 tons (270 to 900 metric tons) of capacity. The market mix option assumes that a fraction of future installations which would use CFC-11 centrifugal chillers could instead use HCFC-22 helical screw chillers (either singly or as multiple part-capacity units).

Quality Engineering. Leaks from mobile air conditioners can be reduced by improvements in design of system components such as the use of shorter and less permeable hoses or the addition of features such as a refrigerant level sensor to shut off the system and alert the driver that the charge has dropped below a certain level. These "quality engineering" improvements could be installed at the factory as original equipment or used as replacement parts on mobile air conditioners after manufacture.

Water Blown HR Systems. Additional use of water-blown high-resiliance (HR) chemical systems for molded flexible foams is a realistic possibility for substantial emission reduction. There may be a penalty in foam versatility, cushioning properties, and part reject rates.

Minimum Foam Density. Most of the auxiliary blowing agent, CFC-11, used in flexible polyurethane foam is used for low density foam. CFC-11 emissions can be reduced by establishing a specification for a minimum foam density.

Add-on Controls. Add-on engineering controls can be used to reduce CFC-113 emissions from solvent cleaning operations. These controls include covers, optimum freeboard height, and adequate drainage of parts being cleaned via drainage racks, hooks, automatic hoists, or equivalent techniques.

Carbon Adsorption. Carbon adsorption is currently used to collect CFCs from a variety of applications. A broader use of this technology is technically feasible.

Food Freezing Alternatives. Liquid food freezing uses liquid CFC-12 to quick-freeze foods. Air blast freezing and cryogenic freezing can replace liquid food freezing. Air blast freezing blows cold air upward through mesh belts carrying the food product. Cryogenic freezing uses liquid nitrogen or carbon dioxide sprayed onto the food.

Aqueous Cleaning. Aqueous cleaning is an alternative to metal and electronics cleaning with CFCs. No solvent emissions occur from this type of cleaning because the cleaning fluid is water-based. Additional aqueous effluent cleanup is necessary.

No Clean Option. A long term option for cleaning of electronic circuit boards is the "no clean approach." This approach would use different fluxes which would not need to be removed from the circuit board.

Hot Vapor Recycle. This is a technique for the control of carry-out solvent loss from conveyorized solvent vapor degreasers. Hot superheated vapor, supplied to a dryer in the degreaser, heats the part being cleaned above the solvent vapor pressure. This method can remove trapped solvent in spaces as small as 0.05 to 0.08 mm.

Improve Controls/Training. The most direct way to reduce unwanted discharges from halon total-flooded fire protection systems is to use improved detection and control equipment. Increasing training of personnel working in halon system protected areas can also significantly reduce releases due to unwanted discharges and fire emissions.

POTENTIAL EFFECTS ON GROUND LEVEL OZONE

Ground level ozone is a secondary pollutant. It is not emitted directly from a source; instead, it is formed primarily as a result of the interaction between VOCs and nitrogen oxides in sunlight. Any increase in the UV-B radiation resulting from a decrease in stratospheric ozone would increase the interaction between VOCs and nitrogen oxides and increase ground level ozone.[5] Therefore, any action taken to reduce stratospheric ozone depletion will help limit development of ground level ozone. Substitute chemicals may be VOCs which would contribute directly to formation of ground level ozone. Global warming will enhance effects of any increase in UV-B radiation reaching the troposphere.[5] Therefore, any substitute chemicals which act as greenhouse gases can contribute indirectly to ground level ozone formation. There may or may not be an increase in ground level ozone formation, since CFCs are greenhouse gases.

Chemical Substitutes

The use of water based solvents for electronic and metal cleaning can completely eliminate organic emissions. The use of petroleum solvents to

replace CFC-113 will increase VOC emissions. Since all terpenes have reasonably high vapor pressures (i. e., are volatile) and are VOCs, it is possible that the recently announced terpene based cleaner to replace CFC-113 for solvent cleaning will be a significant contributor to the formation of ground level ozone.

Hydrocarbons such as pentane and butane are used widely to produce polystyrene foam sheet and are potential replacements for CFC-12 in this application. When polystyrene foams were first introduced, they were blown exclusively with pentane, but the fire hazard caused many plants to change to CFC-12. Local regulation of VOC emissions has been an incentive to convert from hydrocarbons to CFCs for plants still using hydrocarbons. A shift back to hydrocarbons will increase VOC emissions from this application.

One option for reduction of CFC usage for flexible foam manufacture is to switch to methylene chloride. This should not be an ozone problem since methylene chloride, along with 1,1,1,-trichloroethane and several CFCs, were exempted by EPA from VOC limits because they do not react photochemically to produce ozone.

The use of increased water or 100 percent water in the formulation for rigid foam blowing will reduce or eliminate CFC emissions where this option can be used with no effect on VOC emissions.

There may be a tendancy to switch to other organic compounds to replace CFCs in essential aerosol propellant applications. For example, there has already been substitution of dimethyl ether/HCFC-22 mixtures in some essential aerosol applications. This tendency could increase VOC emissions.

An expansion of the use of hydrocarbons for use as refrigerants in industrial process refrigeration systems would contribute to a growth in VOC emissions from this application.

Where the "N_2 purge, then pure EO" option is used for sterilization, there may be more ethylene oxide emissions since any leak would be 100 percent ethylene oxide instead of 12 percent as used in the 12/88 mixture. In addition to the VOC effect, ethylene oxide is also toxic and flammable.

Product Substitutes

The use of alternate insulating materials and other types of product substitutes will generally reduce CFC emissions and would not increase VOC emissions. One exception would be in the switch to substitute food containers. If hydrocarbon blown polystyrene is selected for the substitute food containers, there would be an increase in VOC emissions. At the present time, CFC blown polystyrene comprises only 10 to 30 percent of the polystyrene foam market. The remainder of the market is held predominantly by hydrocarbon blown foam, so the change from CFC may not have a major impact on VOC emissions. Alternate insulating materials will generally have less energy efficiency, so that energy requirements would increase unless the insulating material thickness is increased.

Add-on Engineering Controls/Process Substitution

Add-on engineering controls and process substitution will generally reduce CFC emissions and would not increase VOC emissions. The use of aqueous cleaning, for example, would completely eliminate any organic compound emissions. If VOCs are now present in the process emissions, any add-on engineering controls would probably decrease VOC emissions.

One of the options suggested under quality engineering for mobile air conditioners is for EPA to set up a program of mandatory inspection. Such a program could be combined with other vehicle inspection programs to strengthen the overall program to reduce VOC emissions from vehicles.

SUMMARY

On December 1, 1987, EPA proposed domestic regulations that will fully implement the Montreal Protocol to protect the stratospheric ozone layer. It was decided that allocated quotas offer the most attractive approach to limiting the use of CFCs and halons. This approach should provide for economically efficient reductions. It involves a minimum of administrative costs, is the most easily enforced option, and does not raise any potential legal issues that might result from other options.

Control options that might be used by industry to achieve the necessary CFC reductions are evaluated in the RIA. The most likely long-term control option which may be adopted by most application areas is a chemical substitute. With this option, it may be possible to eliminate 90 percent or more of the ozone-depleting CFC emissions. A variety of control options hold promise for short-term applicability. Some of the engineering controls may still be applied even after new chemical substitutes (e.g., HFC-134a and HCFC-123) are in use, since the higher cost of these substitutes may justify recovery. EPA is also considering the development of specific regulations limiting CFC and halon use for particular industries to supplement allocated quotas.

The most significant impact on ground level ozone formation from implementation of the options to reduce stratospheric ozone depletion appears to be from those options that would use substitute organic compounds which will increase VOC emissions.

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Table I. Control options considered most likely to be adopted

Option	Application[a]						
	1	2	3	4	5	6	7
CHEMICAL SUBSTITUTES							
HFC-134a	LT[b]		LT	LT			
HCFC-123	LT	LT	LT			LT	
HCFC-124	LT						
CFC-11/Water	ST						
HCFC-22			ST				
CFC-502			ST				
HCFC-22/-142b			MT	ST			
CFC-11/HCFC-22	ST						
HCFC-22/Hydrocarbons	ST						
DME/HCFC-22						ST	
Petroleum Solvents						ST	
Methyl Chloroform						ST	
Methylene Chloride						ST	
Perchloroethylene						MT	
10/90 EO/CO_2					ST		
N_2Purge/Pure EO					ST		
HFC-134a/EO					LT		
Hydrocarbons	ST		ST				
Ammonia			ST				
CO_2				ST			
PRODUCT SUBSTITUTES							
Alternate Insulating Materials	ST						
Substitute Food Containers	ST						
Alternate Packaging Materials	ST						
Gasket/Flotation Alternatives	ST						
Alternate Cushioning Materials		ST					
Switch to Disposables						ST	
Modified Stirling Cycle			ST				
ADD-ON CONTROLS/PROCESS MODIFICATION							
Recovery/Recycle			ST			ST	ST
Alternate Leak Test Gas			ST				ST
Market Mix			ST				
Quality Engineering			MT				
Water Blown HR Systems		ST					
Minimum Foam Density		ST					
Add-On Controls						ST	
Carbon Adsorption	ST						
Food Freezing Alternatives				ST			
Aqueous Cleaning						ST	
No Clean Option						LT	
Hot Vapor Recycle						LT	
Improve Controls/Training							ST

a) Application: 1 - Rigid Foam, 2 - Flexible Foam, 3 - Refrigeration, 4 - Miscellaneous, 5 - Sterilants, 6 - Solvents, 7 - Halons

b) Availability: ST - Short Term, MT - Medium Term, LT - Long Term

Table II. Control options considered less likely to be adopted

Option	Applications[a]	Description
Chemical Substitutes		
HCFC-141b	1,2	Developmental substitute
HCFC-124; -123	1	Developmental substitute
HCFC-22/-142b	1,3	Currently available substitute
HCFC-142b	1	Currently available substitute
HFC-134a	1,3	Developmental substitute
HCFC-22	3	Currently available substitute
CFC-12/DME	3	Mixture of 75-85% CFC-12 with dimethyl ether
Innovative Blends	1	Blend of a low ozone depleting CFC with a hydrocarbon
Carbon Dioxide Auxiliary	1	Use carbon dioxide as an auxiliary blowing agent to replace part of the CFC-12
Chemical Blowing Agent	1	Blowing agent such as azodicarbonamide
Hydrocarbons	1,3	Currently available hydrocarbons
Methylene Chloride, Perchloroethylene, Trichloroethane	6	Currently available solvents
Product Substitutes		
Innovative Insulating Materials & Systems	1	New innovative materials and systems (e. g., insulation brick)
Innovative Packaging Materials & Designs	1	New innovative packaging materials and designs
Engineered Plastic Cushion	2	Novel engineered cushioning based on porous plastic
Alternate Refrigeration Cycles	3	Alternate refrigeration cycles (e. g., modified Stirling cycle)
Convert to Gamma Radiation	5	Replace 12/88 sterilization with a gamma radiation facility
Add-on Controls/Process Modification		
Carbon Adsorption	1,2,4	Carbon adsorption system for CFC capture with or without recovery
Incinerate Plant Exhaust	1	Collection of CFC followed by incineration

(Continued)

Table II. Control options considered less likely to be adopted (Continued)

Option	Applications	Description
Formic Acid "AB" Process	2	Flexible foam process using formic acid in place of water in formulation
Modified Polyol Systems	2	Advanced polyol chemicals that can eliminate CFC-11 blowing agent for flexible foam
Vertical Foam Chamber	2	New flexible foam slab equipment system that employs vertical conveyor
Min. Dens. Spec. W/ MeCl Use	2	Combined minimum foam density with expanded methylene chloride substitution
Vert. Foam Chamb. W/ Carbon Adsorption	2	Combined vertical foam equipment with carbon adsorption system
Min. Dens. Spec. W/ Water-blown HR Systems	2	Combined minimum foam density with greater use of water-blown HR formulations
Ban Small Can Sales	3	Ban sale of 14 oz (397 g) cans of CFC-12
Use of Refrigerant Dye	3	Use refrigerant dye to locate leaks
Recovery at Rework, Service, Disposal	3	Recover CFC during rework, service, and disposal of refrigeration equipment
Leak Test Gas Recovery	3	Recovery of leak test gas at installation
Helium Leak Test Gas	3	Use helium for leak testing at manufacture
Acid-Water Scrubber & Condens./Reclamation	5	Acid-water scrubber to convert EO to ethylene glycol followed by non-explosionproof condensation/reclamation of CFC-12
Explosion-proof Condens./Reclamation	5	Explosion-proof condensation/reclamation unit to recover EO and CFC-12
Laundering	6	Some clothes now drycleaned can be laundered
Sprinkler Backup	7	Use water backup to ensure system performance and eliminate need for discharge tests
Training Emissions	7	Use VCR/films, simulators, etc. for training instead of discharging fire extinguishers
OEM Emissions	7	Use alternate test gas or non-destructive test procedures at original equipment manufacture

a) Applications: 1 - Rigid Foam, 2 - Flexible Foam, 3 - Refrigeration, 4 - Miscellaneous, 5 - Sterilants, 6 - Solvents, 7 - Halons